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RESEARCH AND DEVELOPMENT TECHNICAL REPORT
ECOM-5800

STRATOSPHERIC WIND SHEAR COMPUTED FROM SATELLITE THERMAL SOUNDER MEASUREMENTS

By

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September 1976

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The successful operation of thermal sounders on meteorological satellites has provided the atmospheric scientist with a new tool for observing atmospheric structures. This report discusses the application of these measurements to determination of wind shears in the altitude range of 15 to 30 km.

During calendar year 1975 an experiment was conducted at White Sands Missile Range (WSMR), NM, to determine the feasibility of using thermal sounder data to compute stratospheric wind shear. Radiosonde observations were taken over

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20. ABSTRACT (cont)

nearly simultaneously with the overpass of the NOAA-4 satellite. Observations from three radiosonde releases were averaged to provide the in situ data. These results were compared to thermal winds computed from the satellite measurements. Results of this experiment are presented and discussed.

CONTENTS

INTRODUCTION

Successful operation of vertical temperature sounders onboard polar orbiting satellites has provided the atmospheric scientist with a new tool for both observational and inferential analysis of the atmosphere. Several authors (c.f. Yates, [1]) have discussed the capabilities of deducing atmospheric temperature profiles from satellite observations of the thermal radiation emitted by gases of the atmosphere.

Well-known relationships between atmospheric thermal and dynamic structure led Elsberry et al. [2] and Alexander [3] to investigate the possibility of inferring winds from the satellite radiance measurements. An Army application of these principles has been discussed by the author [4].

This report investigates the use of the NOAA-4 Vertical Temperature Profile Radiometer (VTPR) data to infer wind shear in the 15 to 30 km altitude region. Thermal winds computed from the VTPR measurements are compared to wind shears obtained from radiosonde soundings.

DATA

A special data collection was conducted at White Sands Missile Range (WSMR), NM, during 1975 for satellite/radiosonde comparisons. Radiosonde balloons were launched simultaneously from three sites approximately 1 hour prior to the predicted satellite passover time. (This release time was chosen to minimize the errors due to temporal wind variability.) The average of the radiosonde measurements was used as in situ data for comparison with the satellite observations. Thirty-three cases were obtained between 12 February and 18 December 1975.

DISCUSSION

If one assumes geostrophic flow, then the wind shear through a pressure layer (P_1, P_2), $P_1 < P_2$, is given by the thermal wind equations

$$u = -\frac{R}{f}\frac{\partial T}{\partial y}\ln(P_1/P_2)$$

$$v = \frac{R}{f}\frac{\partial T}{\partial x}\ln(P_1/P_2)$$

where R is the gas constant, f the Coriolis parameter, and T the average temperature through the pressure layer.

The VTPR on NOAA-4 scans perpendicular to the subsatellite path to obtain 23 observations along a scan line extending approximately 1000 km to each side. Scan lines are repeated at 73 km intervals. This rather dense grid of observations provides sufficient data for estimation of the horizontal temperature gradients. However, as is typical with numerical differentiation problems, considerable care must be taken in the estimation of the gradients. After a considerable amount of trial and error experimenting, it was concluded that sufficient accuracy could be obtained from a least squares planar fit to a 7 by 7 rectangular array of observations.

Eleven abutting pressures defined by the sequence of pressure 125, 100, 80, 70, 60, 50, 40, 30, 25, 20, 15, and 10 mb were chosen for thermal wind computations. These correspond to altitudes extending from approximately 15 to 31 km. By using the (average) radiosonde measurement at 125 mb as a "tie-on," the wind profile was extended to 30 km by the thermal winds.

RESULTS

The total thermal wind from 15 to 30 km is compared with the corresponding radiosonde measured wind shear in Figure 1. Dots represent the east-west component, while crosses are for the north-south component. Except for a few isolated cases, generally good agreement is obtained. Computed correlation coefficients were 0.786 for the east-west winds and 0.743 for the north-south winds.

More insight is available from Figure 2 which shows the east-west component of the mean profiles. The total shear for the average radiosonde winds is 18.9, which compares well with the total thermal wind of 16.3. However, the thermal wind lags the typical large actual shear in the 15 to 20 km region, is about the same as the actual shear in the 20 to 25 km region, and exceeds the actual shear above 25 km. It should also be noted that the thermal shear for this average case is almost constant with altitude. This is probably due to the limited vertical resolution in the VTPR measurements.

CONCLUSIONS

Results of 33 satellite/radiosonde comparisons have demonstrated that thermal winds computed from the NOAA-4 VTPR observations yield a usable approximation of the actual wind shear from 15 to 30 km altitude. Also, if small layers are considered, then the thermal shear is smaller than the actual shear in the 15 to 20 km region and larger than the actual shear in the 25 to 30 km layer. This phenomenon may have been due to limited vertical resolution of the radiance measurements.

An inspection of the mean profiles (Figure 2) and actual profiles (not shown) suggests that a statistical modification of the computed thermal winds would result in improved accuracies. This possibility is currently being investigated and will be discussed in a subsequent report.

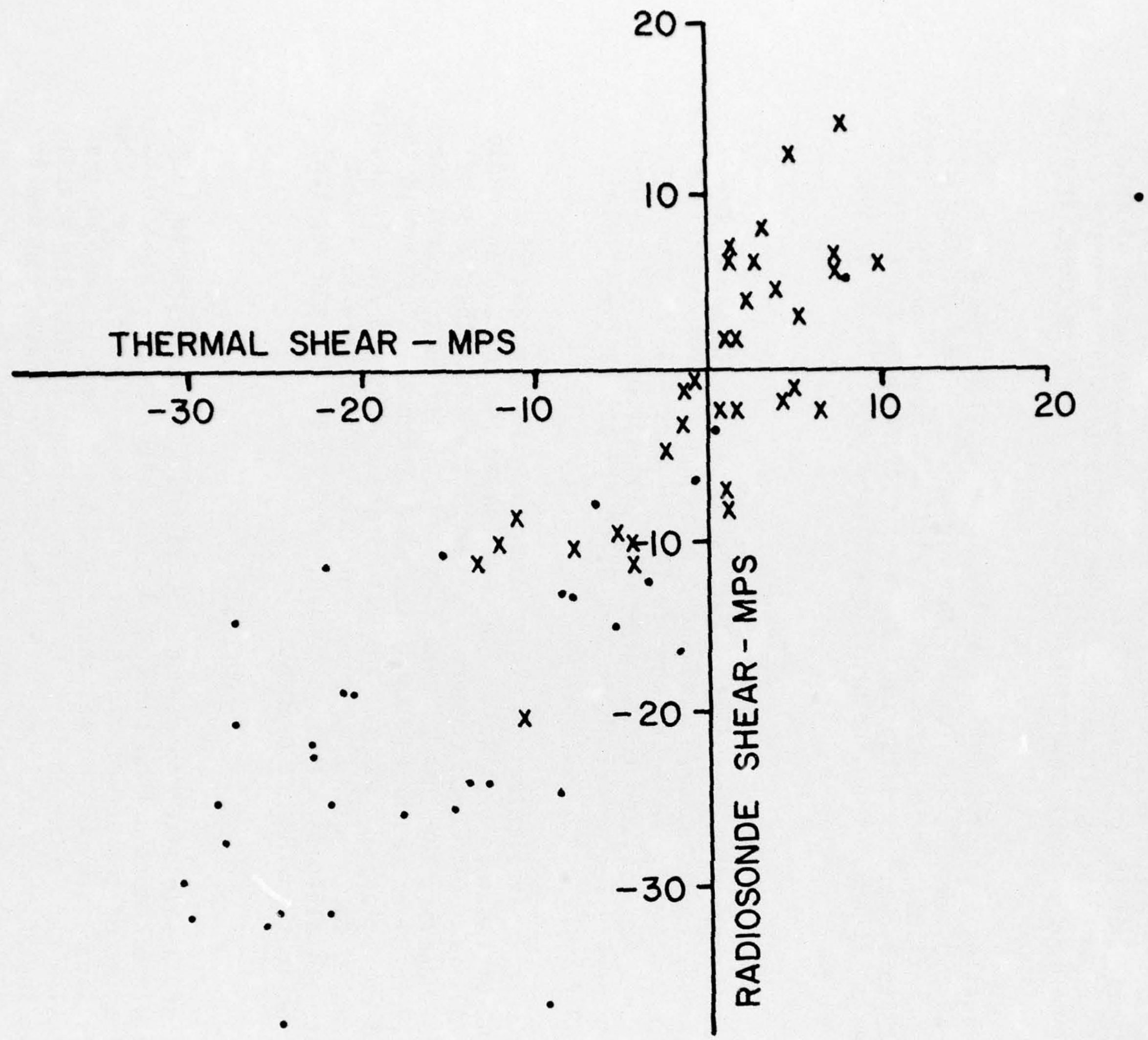

Figure 1. Comparison of Radiosonde and Thermal Shear for 15-30 km Layer.

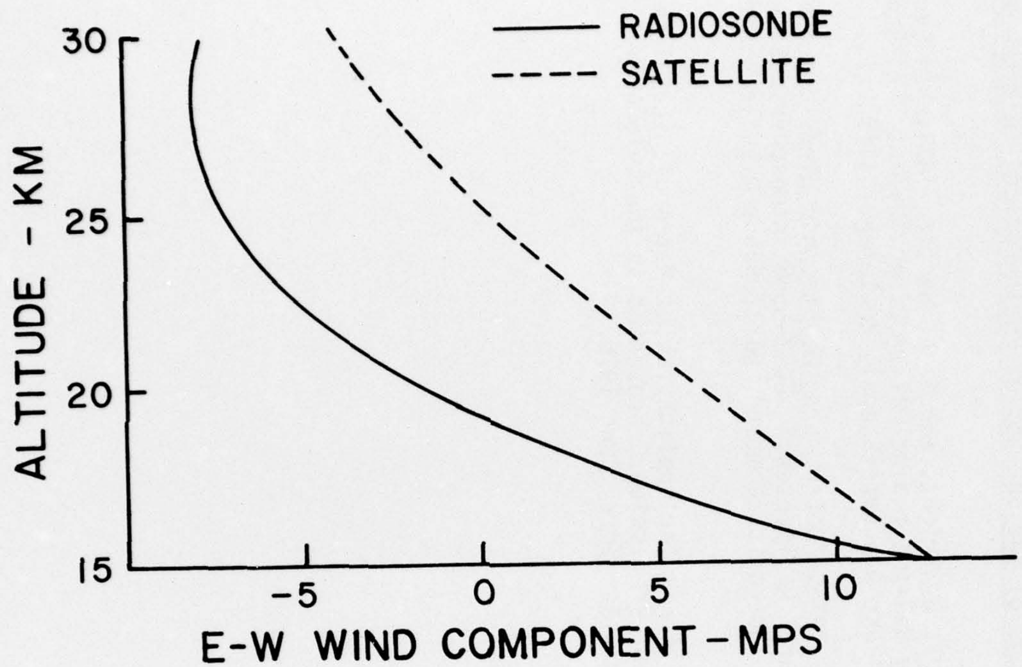

Figure 2. Average E-W Component of Wind Profiles.

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